REVIEW AND ANALYSES OF FARM HARVESTED SIZE FREQUENCY SAMPLES OF EASTERN BLUEFIN TUNA (*THUNNUS THYNNUS*)

Mauricio Ortiz[1], Ana Justel-Rubio[2], and Juan Luis Gallego[1]

SUMMARY

Size frequency data of bluefin tuna harvested at Tuna Farms was compiled, revised and analysis performed for its potential use within the stock evaluation models for the eastern bluefin tuna stock unit. Tuna farms had collected size and weight information from their harvesting operations, and submitted to the Secretariat since 2008. Size, weight, and sex identification data was revised and standardized. There are substantial size samples from harvest operations since 2005 with few reports from prior years; however the main limitation for using this size data is the uncertainty in growth both in size and weight at the farm. Following prior analyses, for all size data was associated to or estimated days-at- farm and using current growth models for eastern bluefin tuna, the expected size at catch was then calculated. In addition, comparing the observed weight at harvest versus the expected weight of equivalent wild-size fish it was possible to estimate the potential weight gain in farming operations. Preliminary results indicated in general a bimodal size distribution for bluefin that goes into farms; first a larger mode about 90-160 cm FL with a peak at 125 cm FL, and a second mode of fish from 170 to 250 cm FL, with a peak at 210 cm FL. However, there are variations in size frequency distribution of farmed fish by year and by flag-farm, as well as by month of capture. Results show some identifiable cohort trends particularly of smaller fish, likely representing population size trends. The time spent in farms is quite variable, from the available data, fish can be in farms from few days up to over 3 years, with a median of 322 days, although the days in farm shows a left skewed type distribution, with 80% of the fish having been in cages for less than 1 year, and a second mode at about 500 days. The weight at size analysis corroborates the gain in weight of farmed fish in function of days at farm, and gaining on average 13% additional weight compared with similar size wild fish.

RÉSUMÉ

Les données de fréquence des tailles du thon rouge mis à mort dans les fermes thonières ont été compilées et révisées et une analyse a été réalisée aux fins de leur emploi potentiel dans les modèles d'évaluation des stocks pour l'unité de stock de thon rouge de l'Est. Les fermes thonières recueillent des informations sur la taille et le poids de leurs opérations de mise à mort et les soumettent depuis 2008 au Secrétariat. Les données de taille, de poids et d'identification du sexe ont été révisées et standardisées. Depuis 2005, il existe de considérables échantillons de tailles obtenus des opérations de mise à mort, avec quelques rapports d'années antérieures ; toutefois, l'emploi de ces données de taille se voit essentiellement limitée par l'incertitude entourant la croissance de taille et de poids à la ferme. Suivant les analyses préalables, pour toutes les données de taille, on a associé ou estimé les jours dans la ferme et on a utilisé les modèles de croissance pour le thon rouge de l'Est pour ensuite calculer la taille escomptée à la capture. En outre, en comparant le poids observé à la mise à mort avec le poids escompté du poisson sauvage de même taille, il a été possible d'estimer le gain pondéral potentiel obtenu dans les opérations d'engraissement. Les résultats préliminaires ont indiqué en général une distribution des tailles bimodale pour le thon rouge qui arrive dans les fermes ; premièrement un mode plus grand d'environ 90-160 cm FL, avec une pointe à 125 cm FL, et un second mode de 170 à 250 cm FL, avec une pointe à 210 cm FL. Toutefois, il existe des variations dans la distribution des fréquences de taille du poisson d'élevage en fonction de l'année et du pavillon-ferme, ainsi que du mois de la capture. Les résultats font apparaître quelques tendances de cohortes identifiables, notamment de poissons plus petits, représentant vraisemblablement les tendances des tailles des populations. Le temps passé dans les fermes est assez variable ; d'après les données disponibles, les poissons peuvent

[1] ICCAT Secretariat. Corazón de Maria 8, Madrid Spain 28002. Mauricio.ortiz@iccat.int
[2] International Seafood Sustainability Foundation. Francisco Giralte 2, Madrid Spain. ajustel@iss-foundation.org

passer de quelques jours à plus de trois ans dans les fermes, avec une moyenne de 322 jours, même si les jours dans les fermes montrent une distribution inclinée vers la gauche, 80% des poissons ayant été dans les cages pendant moins d'un an, et un deuxième mode pendant environ 500 jours. Les analyses du poids à la taille corroborent le gain pondéral des poissons d'élevage, en fonction des jours dans la ferme, qui gagnent en moyenne 13% de poids additionnel par rapport à des poissons sauvages de taille similaire.

RESUMEN

Se compilaron y revisaron los datos de frecuencia de tallas del atún rojo sacrificado en las granjas de atún y se llevaron a cabo análisis para su posible uso en los modelos de evaluación de stock para la unidad del stock de atún rojo oriental. Las granjas han recopilado información sobre talla y peso en sus operaciones de sacrificio y la han estado enviando a la Secretaría desde 2008. Se revisaron y estandarizaron los datos de talla, peso e identificación de sexos. Hay muchas muestras de talla de las operaciones de sacrificio desde 2005 con pocos informes de años anteriores, sin embargo la principal limitación para usar estos datos de talla es la incertidumbre en el crecimiento, tanto de talla como de peso en la granja. Siguiendo los análisis previos, todos los datos de talla se asociaron a, o estimaron, los días en la granja y usando los actuales modelos de crecimiento para el atún rojo oriental, posteriormente se calculó la talla en el momento de la captura. Además, al comparar el peso observado en el momento del sacrificio con el peso previsto de peces de talla equivalente en estado salvaje fue posible estimar la ganancia de peso potencial en las operaciones de cría. Los resultados preliminares indicaban, en general, una distribución de talla bimodal para el atún rojo que va a las granjas, con una primera moda mayor de aproximadamente 90-160 cm FL, con un pico de 125 cm FL, y una segunda moda de aproximadamente 170 a 250 cm FL, con un pico en 210 cm FL. Sin embargo, existen variaciones en la distribución de frecuencias de tallas de los peces de las granjas por año y por granja-pabellón, así como por mes de captura. Los resultados muestran algunas tendencias de cohorte identificable, sobre todo para los peces más pequeños, que probablemente representen las tendencias de talla de la población. A partir de los datos disponibles, el tiempo pasado en las granjas es bastante variable ya que los peces pueden estar en las granjas desde pocos días hasta más de 3 años, con una media de 322 días, aunque los días en la granja presentan una distribución tipo con asimetría hacia la izquierda, con el 80% de los peces en las jaulas durante menos de un año y con una segunda moda de aproximadamente 500 días. El análisis de peso por talla corrobora la ganancia de peso de los peces de las granjas en función de los días en la granja, y la ganancia, de media, de un 13% adicional de peso en comparación con peces salvajes de talla similar.

KEYWORDS

Mean size, Farm bluefin tuna and Size frequency

1. Introduction

In the latest decade, farming of bluefin tuna has become a major destination for most of the catches of the eastern bluefin. In average, for 2005-2011, about 60% of the catch of eastern BFT went to farms (based on catches by purse-seine fleets). Because of the logistics of the fishing operation with live fish, there is very limited information on the size and age distribution of wild bluefin caught and destined to farming. This has rendered in a limited or deficient information input for recent stock assessments, greatly increasing the uncertainty of the results from recent evaluations and stock status determinations (Anon., 2013). In 2008, the ICCAT Commission requested to Bluefin tuna farms to record basic size and weight information of their harvested fish [Rec 2008/05]. Since then, data collected from harvesting operations has been submitted to ICCAT; however the formats, level of detail and completeness of data varied substantially among reporters.

The primary objective of this analysis was to consolidate, review and standardize the available harvesting size and weight information into a database. Afterwards, and following recommendations from the SCRS, analyses were conducted to estimate the size frequency at catch taking into consideration the time at farm and discounting potential growth in size/weight of bluefin tuna. This data will be then used as an input for the stock assessment models.

2. Data

The ICCAT bluefin tuna farm size data started to be reported in June 2008 (2007-2013), following the Rec [08-05]. Initially data was submitted with a form allowing for aggregate data reporting, later this form was updated and only single fish size/weight measures were accepted. In addition, some CPCs submitted size data from their farms harvesting operations prior to 2008 (2004-2006), however most of these data were aggregated and no information of the completeness (percent of total harvesting) was provided. Also, in 2011 the Regional Observer Program (ROP) for bluefin tuna started to collect the size and weight information from harvesting operations. In some instances, CPCs deferred the size data reporting to the ROP program; however, some other reported it twice under the ICCAT Stats Task-6 form and the ROP. Finally, and following the SCRS recommendations, some individual farms have kindly provided harvest data operations from 1996 to 2014. A database was created identifying each harvesting operation (per day when available) by registered farm and the corresponding size/weight data for the fish harvested and measured. Due to duplicated submissions, the initial task was identifying and removing duplicated records. A record was considered as duplicate if they had the same Farm ID (ICCAT farm code number), same date of harvesting, and the number and size frequency of the fish reported were similar. Almost all of the size measurements are reported in 1 cm size bin (296,683 records); however some were reported in 2 (59), 5 (2174) and 10 (59) cm. Reports of size in 10 cm were excluded, while reports of size in 2 and 5 cm were converted into 1 cm, by splitting the number of fish per size bin randomly and distributing them uniformly among 1 cm bins. The compiled database included size sampling from 3 main sources covering harvesting operations from 1996 to 2014. **Table 1** summarizes the distribution of records by year and source of information, and **Table 2** indicates the number of record considered duplicates. Overall, 13% of records were submitted at least twice, of which only a single copy with the most complete data was kept in the database for a total of 257,574 records. The size farm database includes 295,718 fish measured from harvesting operations between 1996 and 20143. Of these, there are 4,415 identified individual harvest operations (e.g. having farm ID and date of harvest) with corresponding 235,893 measured fish (80%), while the rest are missing the date of harvest or the farm (59,825 measured fish). It is common that farm size sampled fish also include weight information; about 45% of the records have size and weight measurements, 46% only size and 9% only weight. However, in some cases weight was estimated by a relationship rather than measured and it is not possible to distinguish between the two cases. A small proportion of records also included sex identification (16,631 or < 6%).

Other information requested within the farm size reports, included the total original catch (numbers and weight) and date of the catch from which the reported harvest operation originated. However, only 1,831 harvest operations (41%) provided the original catch date. In the case of the data from the ROP each record was associated to the Bluefin catch document (BCD) corresponding to the harvest operation, by linking this information with the ICCAT BCD database it was possible to get the date of the catch.

2013-2014 Partial submissions up to the date of this analysis.

The database comprise harvests from 43 registered farms corresponding to 8 CPCs; EU-Croatia, EU-Cyprus, EU-Spain, EU-Greece, EU-Italy, EU-Malta, Tunisia and Turkey. Some of the records prior to 2008 have no farm identifier as data were submitted as aggregated information by the CPC. In the original data for size type of measurement, 61% were reported as fork length (FL), 22% curved fork length (CFL), 8% straight fork length (SFL), 3% total length (TLE), 7% in length 1st dorsal fin (LD1) and less than 0.3% had no size measurement type. All size measurements were converted to FL (cm) using the current SCRS adopted size relationships for E-BFT as indicated below.

Reported Size Type	*Conversion used*	*Reference*
CFL	FL = 0.955*CFL	Parrack *et al.* (1979)
TLE	FL = TLE	
LD1	FL = 2.0077*LD1^1.14	Rodríguez Marin *et al.* (2012)
SFL	FL = SFL	

Over 48% of weight measures were reported as whole weight (WH), 41% as round weight (RW), 2% as dress weight (DR), few (<1%) in gilled and gutted (GG), and the rest blank. All were converted to round weight units using the following relationships.

Reported Product Type	*Conversion used*	*Reference*
DR	RWT = 1.25*DR	Anon. (2003)
GG	RWT = 1.16*GG	Unk
WH	RWT = WH	

For records with only weight measures, no estimation of size was done. Once size and weight units were standardized to FL (cm) and RW (kg), size frequency in 5 cm bin (mid-point) classes were estimated for further analyses.

As mentioned above, data covered farming harvest from 1996 to 2014, however only from 2005 until 2013 there are over ten thousand reported fish measures (**Figure 1**) per year, being 2007 and 2008 the years with the highest number of fish measured. By farm CPC, Spain and Turkey are the top two reporters accounting for 68% of size measures, followed by Croatia (11%), Malta (8%), Tunisia (6%), Italy (3%), Greece (2%) and Cyprus (1%).

Figure 2

Figure 2 shows the distribution of farm size samples by year and farm/flag. **Table 3** shows the number of fish samples and reporting farms by Flag and year. The number of reporting farms per year has varied, being 2007-09 the year with highest number of active farms with about 25, in years 2010/11 there were 18 and 22 respectively. By Flag, Spain reported from 11 different farms, followed by Turkey and Croatia 8, and Malta 5.

3. Methods

Initially analyses were performed on the size and weight distributions to identify potential outliers or series non consistent with the general trend of the data. **Figure 3** shows a box plot distributions of the weight at size (FL 5 cm bin size). In 2013 records were identified from a single farm (EU-Spain 2007-09) that reported about 40,000 size measurements of which a significant proportion were reported as LD1 type. However it was suspected that this was due to an error in type of measure; analyses of size frequency distributions and their relationship size-weight corroborated that all size measures were likely FL and records were corrected (**Figure 4**). Size records were considered outliers if FL < 30 cm or FL > 500 cm, overall fish smaller than 100 cm FL represent less than 1% of all size samples, while fish larger than 300 cm FL represent less than 0.006% (**Figure 5**). Similarly records with reported round weight greater than 800 kg were considered outliers and excluded from further analysis (**Figure 6**).

As the main objective of this research is to estimate bluefin size distribution at capture, it was assumed that growth in size of farmed bluefin tuna is similar to wild fish. Therefore if it is known the size at harvest and the time (days) in the farm, it is possible to back estimate the size at catch, using a growth function for eastern bluefin. Briefly, with size at harvest by inversion of the von Bertalanffy growth model it was estimated the age at harvest, then the expected size of the fish at age minus days at farm was estimated. The first step was to estimate

the days at farm for those records that did not report date of capture (59%). The approach for this case was to use the subset of data that did reported date of capture and to estimate mean days-at-farm by each Flag, farm and year; then these values were assigned to records without catch date. In few cases where the farm ID was missing, then a mean by Flag-year was used. **Table 4** shows the estimated mean days at farm by Flag, farm ID and year for those records that reported harvest and catch date information or records where the catch date was extracted from the bluefin catch document (BCD) associated to the harvest operation (ROP-MRAG data). There is substantial variability in the days at farm by flag and farm (**Figure 6**) however there is a general trend of increasing the time at farm for bluefin particularly in the recent years. On average bluefin stay on farms for 350.3 days, but there is a wide range of caging days from 105 to 1134 (95% quantile) with a left skewed and binomial distribution, the median days at farm is 209 days. The maximum time in farm is over 5 years, 1968 days; however this information has not been confirmed. Although there is limited information on gender of harvested bluefin (16,637 fish), sex-ratios by year indicated not major departure from a 50% distribution of catch.

4. Results and discussion

Size and or age distribution of removals is an important input for most fisheries assessment models (Haddon 2001). It is particularly important for stocks that are highly exploited as is the case for eastern bluefin tuna. Size/age information is routinely collected through sampling programs on important fisheries usually at dock or transfers of the catch to markets. However, in the case of eastern and Mediterranean bluefin, in the last decade(s) the fishery has shifted from immediate market of the catch towards bluefin farming operations where the product can reach better market quality and provide control of supply-demand (Mylonas *et al.* 2010). As such, an increased percent of the catches of the allocated quota is realized by the purse-seine fleet which is delivered to different farms within the Mediterranean Sea. The catch operation and transfer of live fish to cages in the farms limited substantially the possibilities for obtaining reliable size measures of the catch. There have been proposals to implement visual and electronic sampling protocols, but these methodologies are still under development and testing (Yildirimd *et al*. 2012 and SCRS/2012/053, SCRS/2012/133, Grubisic *et al*. 2012), meanwhile the scientific working group has recognized the increased uncertainty of their analyses in part due to the limited size sampling of this important component of the catch. Presently, at the end of the farming, bluefin harvested is required to be sampled for size, weight and biological information when possible. It has been recognized that farming operations do translate into gains in weight and size of the fish, however this increase is quite variable and the few reports available show a great level of variation. These studies have further identified a wide number of potential variables that affect growth both in size and weight of bluefin inside farms, among others feeding, temperature, location, water quality, density of fish, etc. In general, it is accepted that most gain is in weight rather than in size, given in part that the fish remain for relative short time in farms (less than a year).

Since 2008 farms are obliged to submit information of their harvested fish, in size and weight at least. Some CPCs have submitted size samples for earlier years from their farms. Size frequency distribution of the farm fishes can potentially be used to infer their size at catch. For this it would be necessary to know the time of caging for each fish, and a growth discount hopefully taking into consideration factors that affect farming growth as mentioned before. The initial task was to consolidate the size data obtained from different sources; reports from CPCs (Task SZ6), regional observer program (ROP-MRAG) and by farms (Farm). Once the data was consolidated a quality control of the information was performed. Initial analyses using the weight-size relationship of harvested fish, clearly indicated some inconsistencies in the data that were revised and corrected.

Size at catch was calculated by assuming a similar growth in size for farm and wild fish, and estimated by using the current growth model for eastern bluefin tuna applied in the catch at age algorithms with the von Bertalanffy model parameters of asymptotic size (Linf) 318.9 FL cm, K 0.093 and t0 -0.97 (Cort 1991). Overall the estimated size frequency catch (5 cm bin size mid-point) for farmed bluefin shows a bimodal distribution with a range of sizes from 30 to 320 FL cm (**Figure 7**), a larger peak is about 130 FL cm and a second peak at 215 FL cm. By year, the bimodal trends still remain, and it is possible to identify cohorts moving through the catch size distribution (**Figure 8**). Also, by month there is a trend in the catch size distribution with smaller fish being caught early in the year, while larger fish appear in May, June with also the larger catches (**Figure 8**). Finally, by farm flag, EU-Croatia catches primarily small bluefin, while other countries show more the bimodal distribution type (**Figure 9**). In terms of number of size samples, prior to 2005 there are less than 600 samples between 1996 and 2003. For the early years 1996-1999, density size plots show catches of larger size fish (> 170 FL cm) mainly. For 2000 to 2004 a bimodal distribution is more apparent (**Figure 10**).

Analysis previously done (Ortiz *et al*. 2013) of the weight at size relationship indicated that estimates of weight at size from farmed fish are in the upper quantile of the wild fish weight at size models (**Figure 11**). Further analyses done with non-linear quantile regression analysis (Cade and Noon 2003, Koenker 2009) (a procedure

that relaxes from the assumptions of normal distribution about the predicted mean and variance of weight at size) also show that the estimated mean weight at size is greater for farmed fish, notable for fish over 200 cm FL. These were also the case with the updated size-weight data.

As we have estimated size at catch and have available size at harvest, by using the size-weight conversion factors it was possible to estimate the predicted gain in weight that would correspond to wild fish. Comparing this value to the reported weight of the farm harvest of each individual fish, then we could infer the potential gain in weight during and due to farming. This is a proxy of course; however the distribution of the difference between predicted weight at harvest and the reported weight actually shows an overall gain in weight associated with farming (**Figure 12**). The results indicate an overall gain in weight of 13% due to farming compared to similar size wild fish and that about 80% of the fish in farms do gain weight (CDF plot). The 80% quartile range indicates a weight gain between 0 and 40%.

The information on farm catch and harvesting by sex showed overall an equal proportion of males and females by year (**Figure 13**). When the sex ratios were fitted to size results indicated a trend of slightly higher male proportions for fish larger than 300 FL cm size. However, the significance of the logistic regression fit is marginal and the predicted odds ratio is very close to 1 (1.00068), indicating rather an equal ratio of sex at size of farmed bluefin tuna.

In conclusion the size samplings at harvest of farmed bluefin provide size frequency distributions since 2005, but the main restriction is the estimation of days at farm as it is still not commonly reported or unavailable for historic records. In this analysis we use the average days-at-farm by year and farm from reported data to fill up missing information, assuming that farming operations have been consistent in time. An average days-at-farm should be estimated at the farm level at least, as these are quite variable when compared among farms even for the same country. It is strongly recommended that reports from harvesting operations include the complete BCD number of the fish killed.

The estimated size distribution at catch shows a bimodal distribution for bluefin, under the assumption that only purse seine vessels supply fish to farms, it is noticeable that two distinct size classes are being caught by this gear. The first size mode is about 100-150 cm FL, and the second mode of larger fish between 190 and 250 cm FL. Why the intermediate size fish are not caught in similar proportions by the purse seiners? One possible explanation is that the yearly trends may indicate that only two main cohorts are likely the major contributors to the PS catch destined to farms. Also the monthly trends corroborate the so-called size dependent migration into the PS fishing area. The data shows that there have been variations in mean size of farmed fish by year and by flag-farm, likely representing population size trends.

The time spent in farms is also quite variable. From the available data, fish can be in farms from few days up to over 1.5 years, with a median of 209 days; although the days in farm distribution shows a bimodal type distribution, with a higher proportion of the fish having been in cages for about 150-200 days, and a second mode at about 600 days. The weight at size analysis corroborates the gain in weight of farmed fish, compared to similar size wild fish; farmed bluefin gain over 13% in weight with a 0.8 probability of gaining weight.

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Table 1. Summary of the number of farm harvest size sampling records compiled for bluefin tuna 1996 – 2014. Main sources are FARM records provided directly by BFT Spanish farms, Regional Observer Program ROP–MRAG, and the Secretariat Task 6SZ database reported by CPCs.

Number of records	*Data Source*			
Year Harvest	*FARM*	*ROP*	*TSZ6*	*Total*
1996	129			129
1999	701			701
2000	58			58
2001	160			160
2002	64			64
2003	51		49	100
2004	134		695	829
2005	269		6091	6360
2006	3370		4942	8312
2007	9984		36778	46762
2008			32488	32488
2009	1608		27001	28609
2010	8670		13901	22571
2011	11306	29063	16513	56882
2012	9137	50118	12468	71723
2013	5716	7675	3871	17262
2014	3673			3673
Grand Total	**55030**	**86856**	**154797**	**296683**

Table 2. Number of identified duplicated records by Farm Flag CPC among the size sampling information compiled from the three different sources indicated in **Table 1**.

Farm State		*Duplicate*	*Total*
EU-Croatia	27629	3040	30669
EU-Cyprus	2322		2322
EU-Greece	4521	984	5505
EU-Italy	1800	28	1828
EU-Malta	32045	6954	38999
EU-Spain	131261	25572	156833
Tunisie	17347	997	18344
Turkey	40649	1534	42183
Grand Total	**257574**	**39109**	**296683**

Table 3. Number of bluefin tuna harvested from farms and sampled for size by flag and farm. Data for 2014 represents partial submission.

Farm Flag	FarmID	1996	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
EU.Croatia									89		3232	3034						
	AT001HRV00001												166					
	AT001HRV00002												276	117				
	AT001HRV00003												1064	955	5376	914	4095	
	AT001HRV00004												484					
	AT001HRV00006												972	1001	2033	3345		
	AT001HRV00007															1		
	AT001HRV00008													1072	1607	1561	1240	
	AT001HRV00009												429		243			
EU.Cyprus									1207	683								
	ATEU1CYP00001										489							
	ATEU1CYP00002											280						
	ATEU1CYP00003										600	479						
EU.Greece											433							
	ATEU1GRC00001									507	300		67	991	1007	783	550	
	ATEU1GRC00002																40	
EU.Italy								1924	3608	3132								
	ATEU1ITA00001								150				280					
	ATEU1ITA00006														770			
EU.Malta									3997		1221							
	ATEU1MLT00001										1897	1490	751	355	1132	1993		
	ATEU1MLT00003										992	413	640	367	366	1543		
	ATEU1MLT00004										443	504	108	570	117	516		
	ATEU1MLT00007										709	888	369			126		
	ATEU1MLT00008										63	559	674	743	634	893	2	
EU.Spain									951	12045	2795							
	ATEU1ESP00001				109	32		134	97		942					331	28	
	ATEU1ESP00003										4781	4210	4107		6531	7561		
	ATEU1ESP00004														224	1510		
	ATEU1ESP00005									2996	11127	11893	2841	8670	15293	11895	4566	3673
	ATEU1ESP00006								22	373	9104	1326						
	ATEU1ESP00007											4201						
	ATEU1ESP00009										258							
	ATEU1ESP00010										734							
	ATEU1ESP00011	129	701	58	51	32	51				2175	774						
	ATEU1ESP00013										589	1040	510					
	ATEU1ESP00014										48							
Tunisie	AT001TUN00001										501	815	262	686	290	945	408	
	AT001TUN00002										796	675	629	1239	1768	1626	762	
	AT001TUN00003										745	1682	255	368	57			
	AT001TUN00004										196	577	468	516	119	1298	268	
Turkey							101	7880	3397	3128	6968							
	AT001TUR00004											1101	3091	1382	733	263		
	AT001TUR00005												2781	1281	1481	557	1576	
	AT001TUR00006											93	432	2320	1889	416		
	AT001TUR00010											266	624					
	AT001TUR00011											72			5469	4262		
	AT001TUR00012												3086					
	AT001TUR00013											1189	981	896	788	416	669	
	ATEU1ESP00004																	
Total		129	701	58	160	64	152	9938	13518	22864	52138	37561	26347	23529	47927	42755	14204	3673

Table 4. Estimated mean days-at-farm for eastern bluefin tuna by farm and year from records that reported harvest and catch date, or catch date was directly extracted from the bluefin catch document (BCD) associated to the harvesting operation (ROP database).

Farm State	FarmID	1996	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
EU.Croatia																	
	AT001HRV00001																
	AT001HRV00002																
	AT001HRV00003															1480.6	1156.0
	AT001HRV00004																
	AT001HRV00006															573.0	
	AT001HRV00007																
	AT001HRV00008																728.9
	AT001HRV00009																
EU.Cyprus																	
	ATEU1CYP00001																
	ATEU1CYP00002											161.5					
	ATEU1CYP00003											141.7					
EU.Greece																	
	ATEU1GRC00001												395.2	267.4	486.5	380.5	561.5
	ATEU1GRC00002																276.0
EU.Italy																	
	ATEU1ITA00001																
	ATEU1ITA00006														149.0		
EU.Malta																	
	ATEU1MLT00001												143.0		592.0	198.7	
	ATEU1MLT00003												157.1	214.3	340.2	193.8	
	ATEU1MLT00004													208.3	452.0	182.3	
	ATEU1MLT00007												162.8			497.6	
	ATEU1MLT00008												141.3	190.8	191.0	190.3	
EU.Spain																	
	ATEU1ESP00001															213.5	57.1
	ATEU1ESP00003												80.7		195.2	194.1	
	ATEU1ESP00004														121.3	131.3	
	ATEU1ESP00005												149.1		314.7	467.8	906.8
	ATEU1ESP00006																
	ATEU1ESP00007																
	ATEU1ESP00009																
	ATEU1ESP00010																
	ATEU1ESP00011																
	ATEU1ESP00013																
	ATEU1ESP00014																
Tunisie	AT001TUN00001												151.1	171.8	23.2	184.0	
	AT001TUN00002												35.4	345.5	212.4	203.6	52.0
	AT001TUN00003												112.1	275.7	277.4		
	AT001TUN00004												187.5	156.0	24.3	163.0	
Turkey																	
	AT001TUR00004											198.0	230.2	259.7		590.8	
	AT001TUR00005												323.3	560.5		238.7	
	AT001TUR00006											166.0	431.5	570.0		526.6	
	AT001TUR00010											43.0	236.9				
	AT001TUR00011														131.9	553.4	
	AT001TUR00012												382.0				
	AT001TUR00013												276.8	363.9	377.0	246.0	
	ATEU1ESP00004																

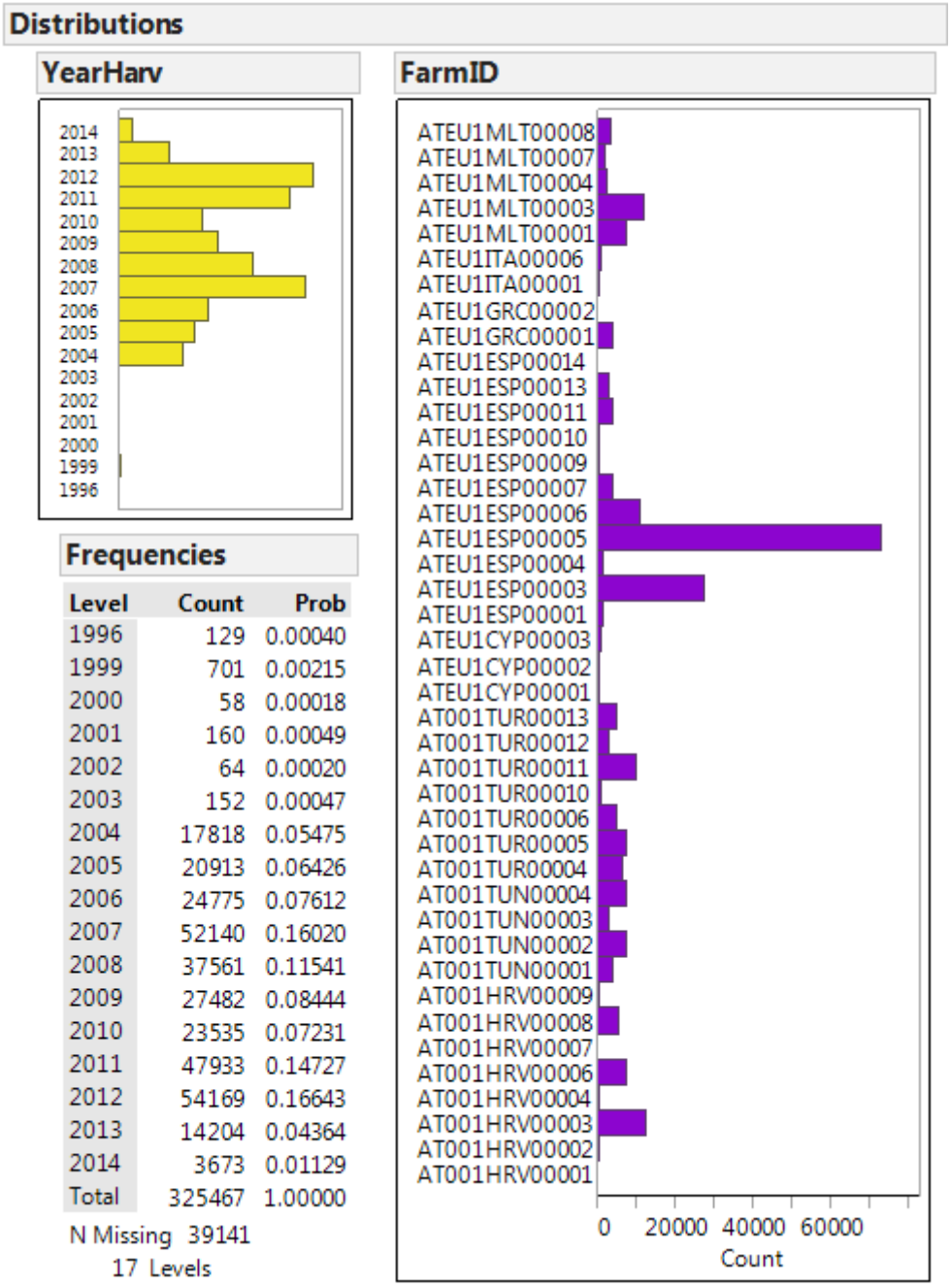


Figure 1. Distribution of farm size samples per year and by farm ID. Values represent the number of fish harvested and size measured.

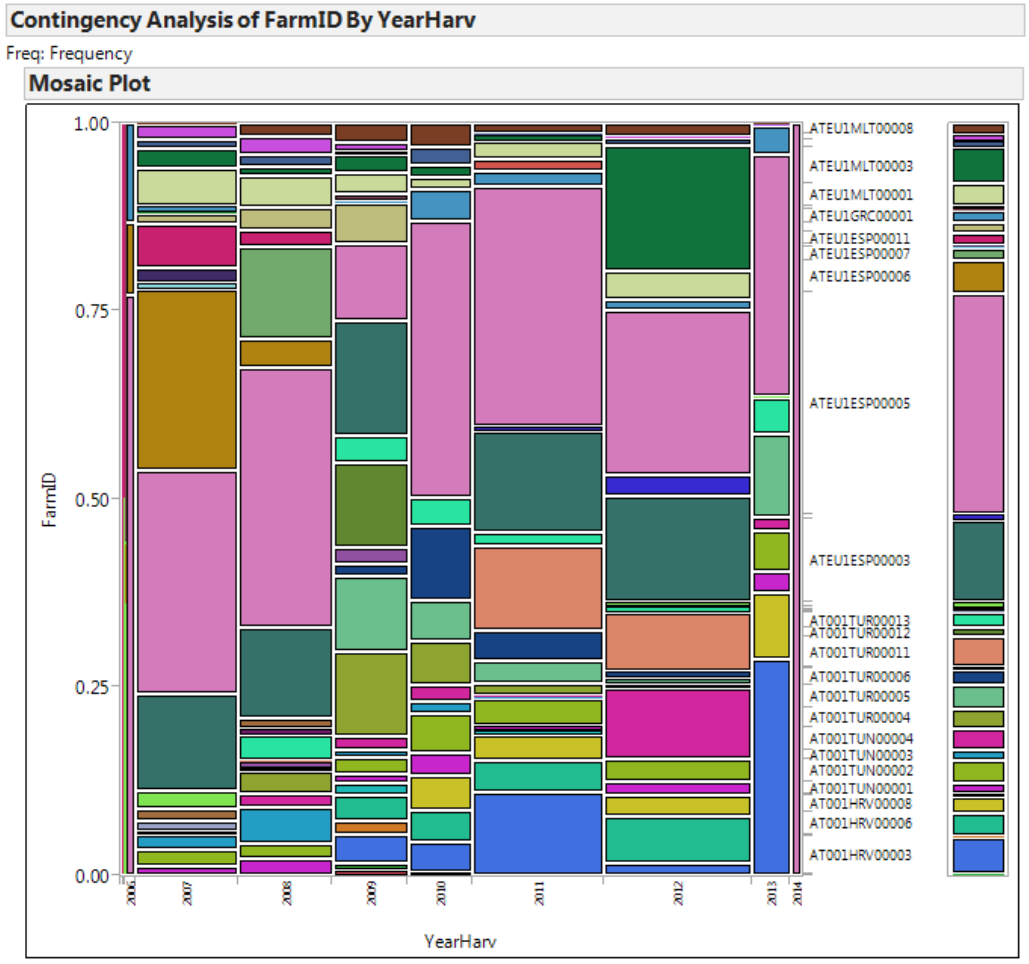


Figure 2. Mosaic plot of the number of farm size samples E-BFT by year and farm ID, color code for the same farm flag.

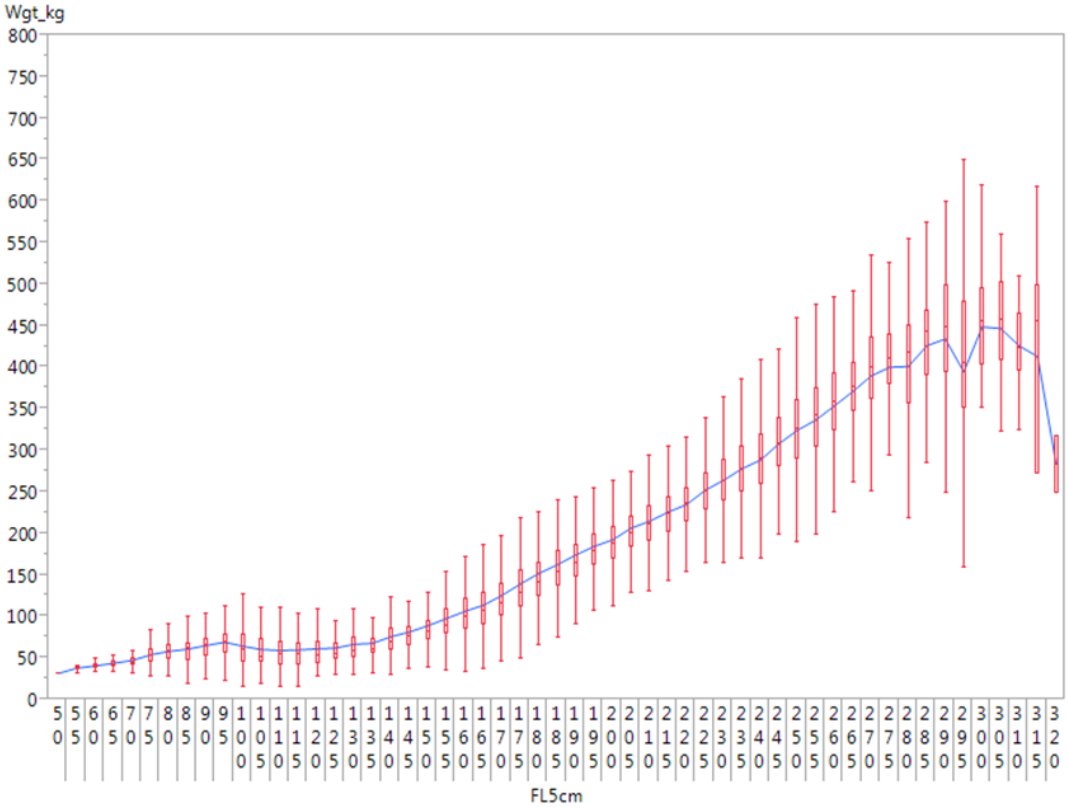


Figure 3. Box-plot distributions of weight (RW kg) at size (FL 5 cm) for farmed BFT DB.

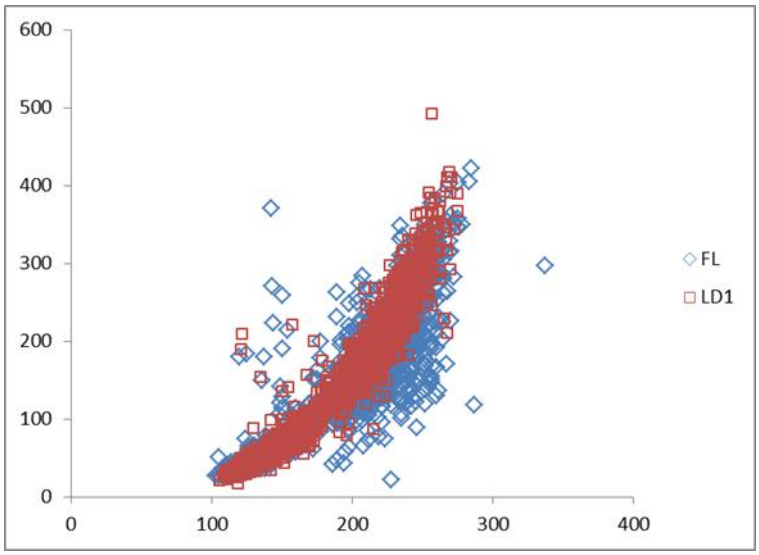


Figure 4. Comparison of the Size - weight scatter plot distributions from the same farm (2007-2009) that reported some measurements as LD1 type, whilst the majority were reported as FL.

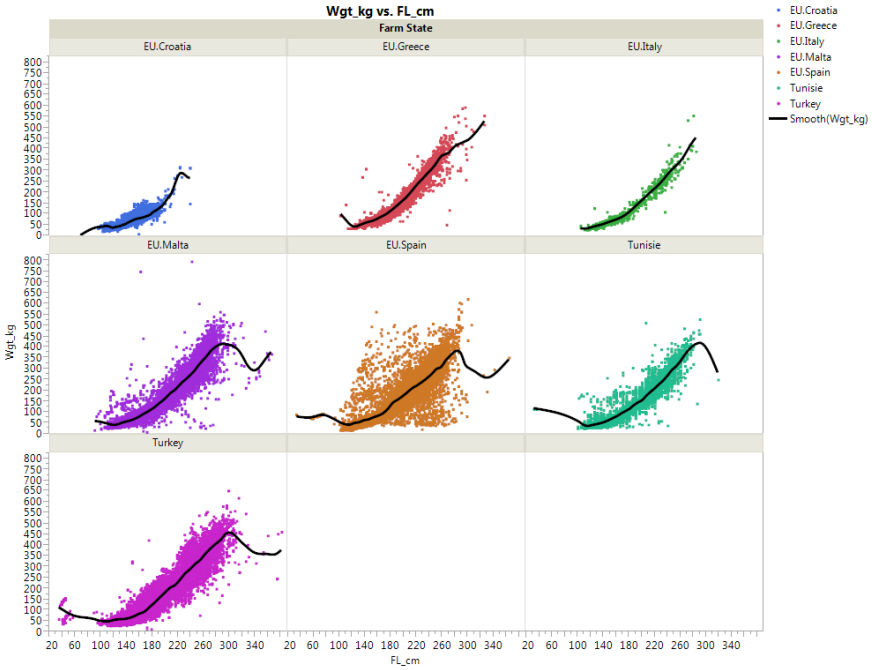


Figure 5. Scatter plot of weight (RWT kg) and size (FL cm) of E-BFT harvested at farms by CPC-flag of farm.

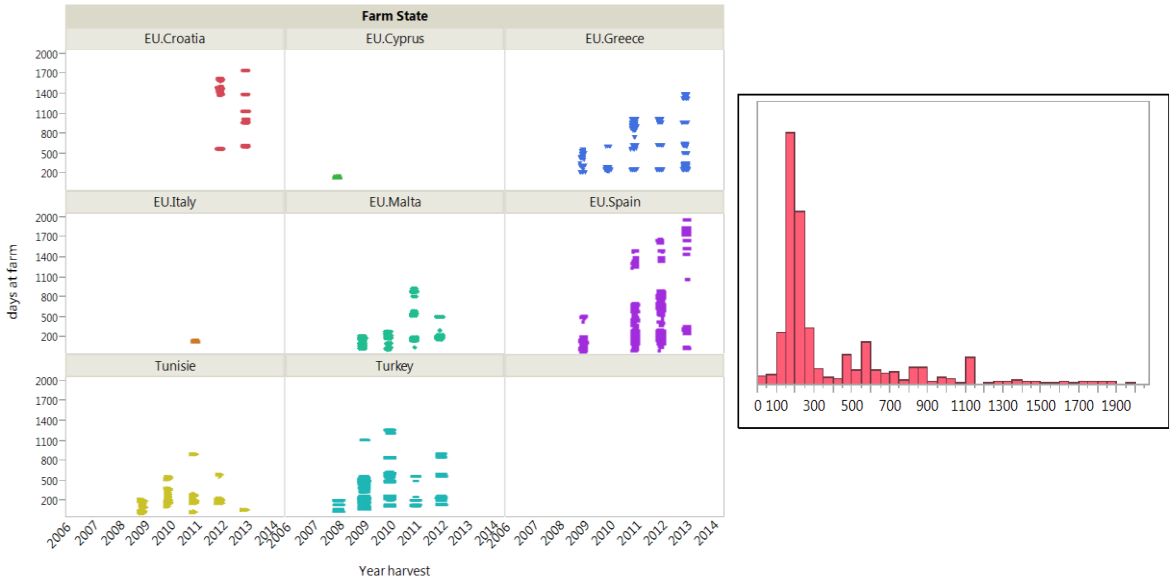


Figure 6. Scatter plot of days at farm by flag state and harvest year (left) and frequency distribution of the mean days at farm (right).

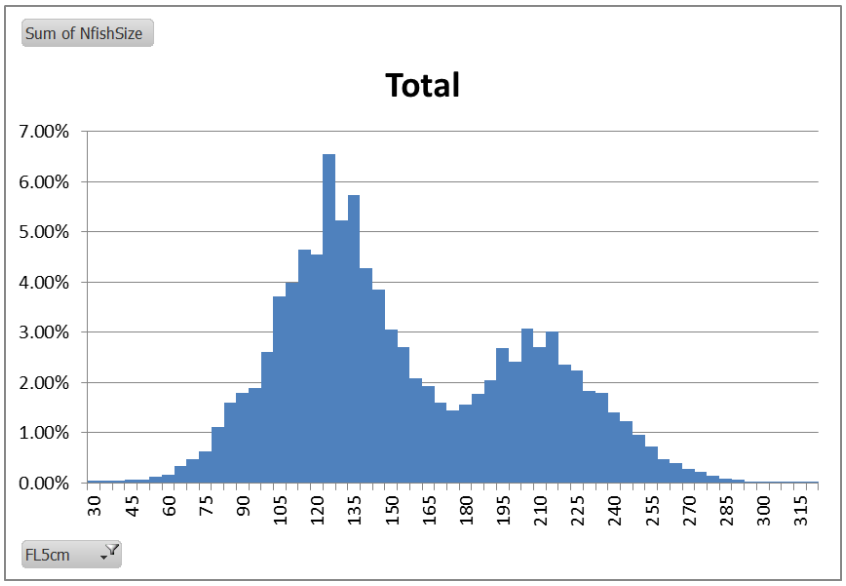


Figure 7. Estimated size frequency density of harvested E-bluefin tuna (FL cm) at the time of catch all years.

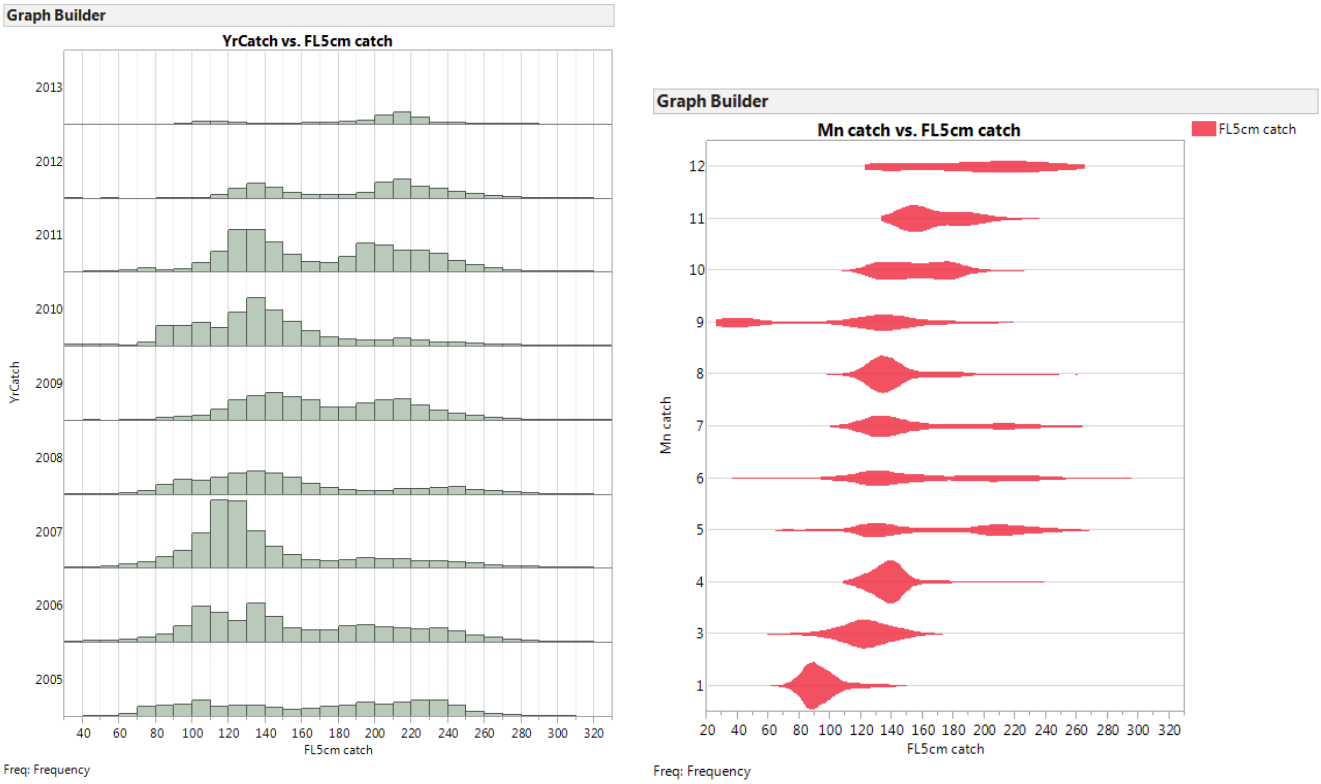


Figure 8. Estimated size frequency distributions of harvested E-bluefin tuna (FL cm) at time of catch by year (2005-13) and by month.

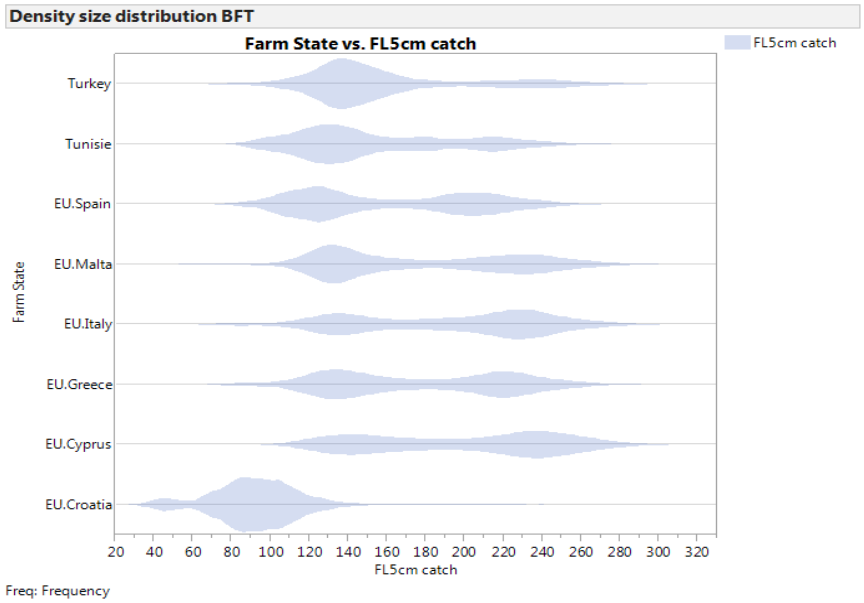


Figure 9. Size density distribution of BFT at catch from the farm harvest database by farm flag.

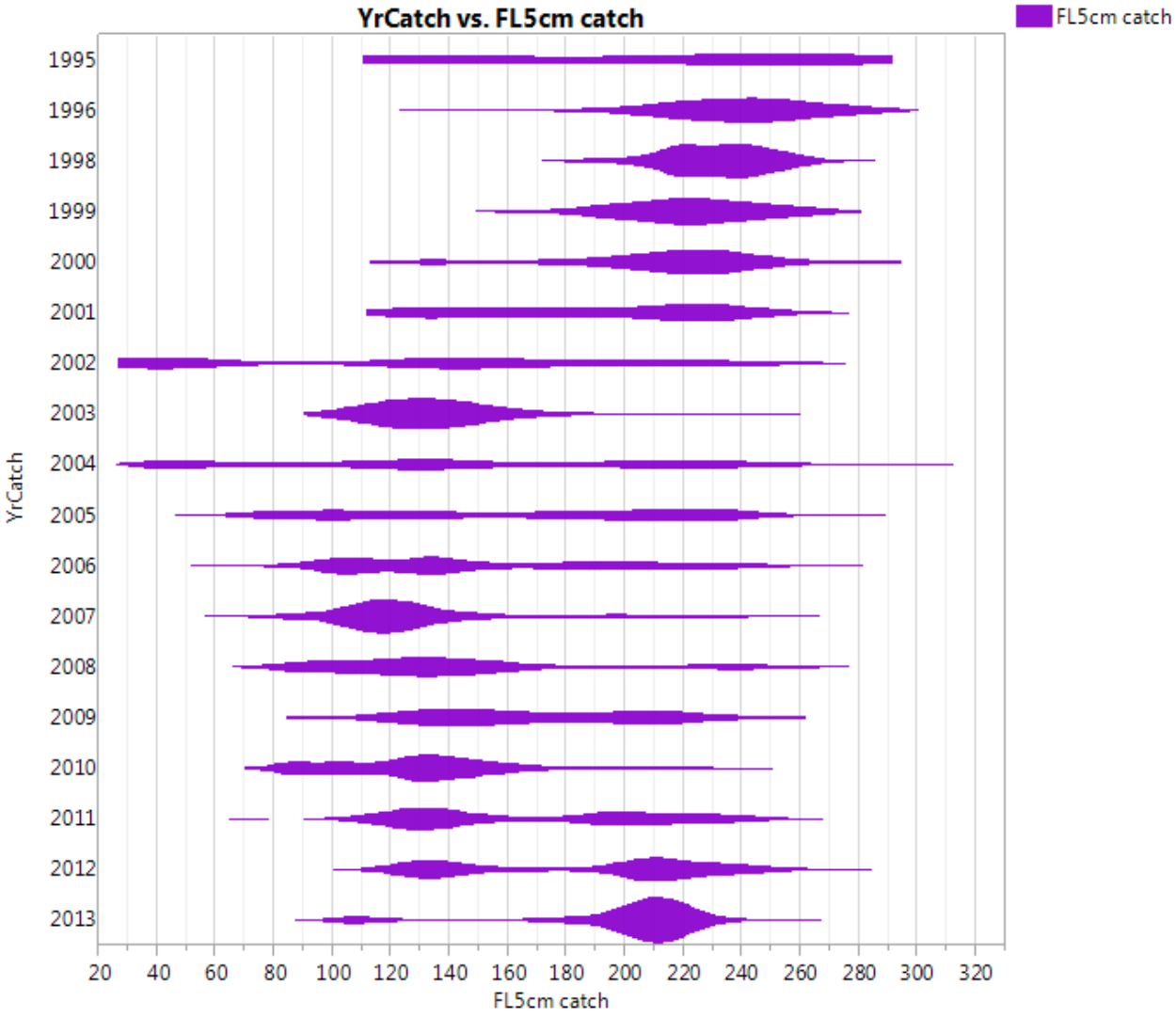


Figure 10. Size density distributions of harvest E-BFT at time of catch by year. 1995-2013.

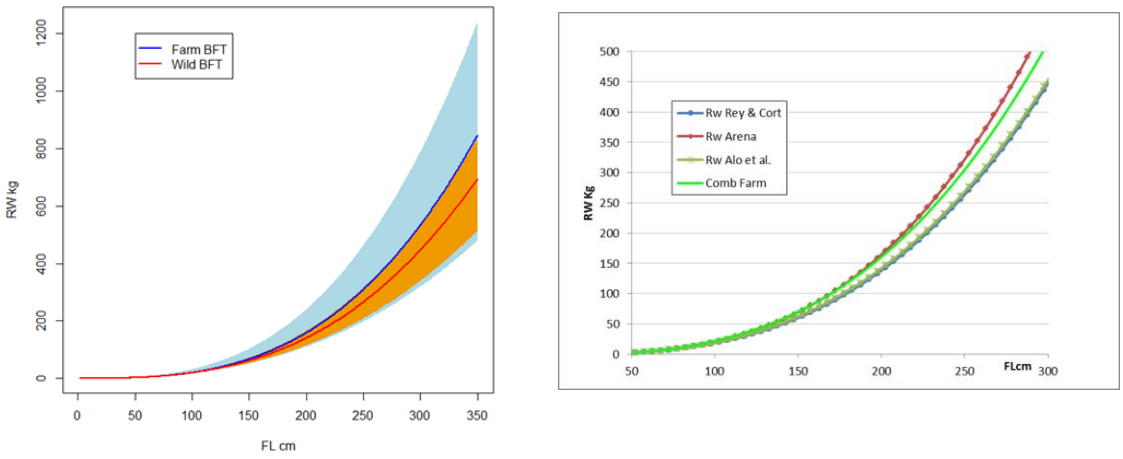
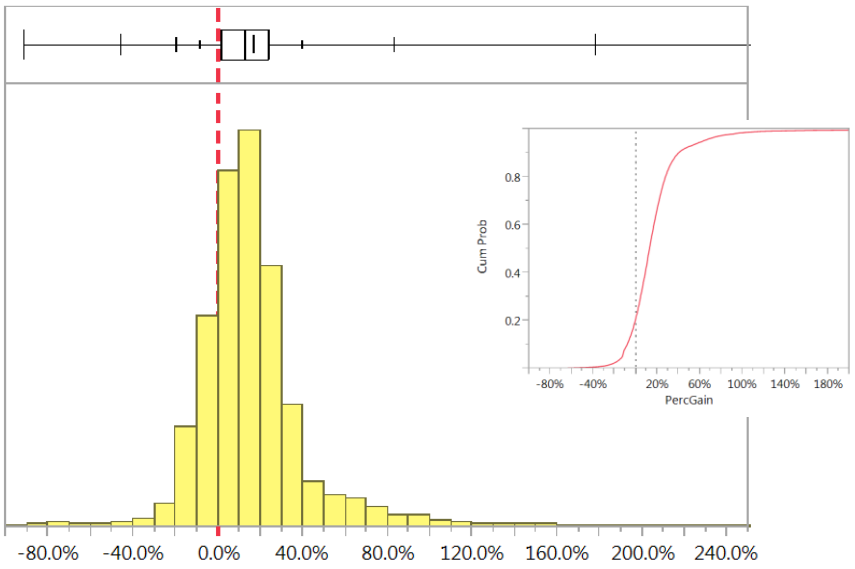


Figure 11. Comparison of the 95% quantile regression estimates for bluefin tuna weight at size from farm harvest fish (blue shade, and solid blue line) and wild fish (orange shade and red line). Data of wild fish was kindly provided by IEO scientists SCRS/2012/104.



Quantiles

100.0%	maximum	8.66908
99.5%		1.77802
97.5%		0.83247
90.0%		0.39852
75.0%	quartile	0.24389
50.0%	median	0.12738
25.0%	quartile	0.0208
10.0%		-0.0812
2.5%		-0.195
0.5%		-0.4525
0.0%	minimum	-0.9132

Summary Statistics

Mean	0.1694911
Std Dev	0.3390327
Std Err Mean	0.0009341
Upper 95% Mean	0.171322
Lower 95% Mean	0.1676602
N	131724

Figure 12. Frequency distribution and CDF of the estimated gain in weight for farmed bluefin tuna estimated as the difference in observed weight at harvest and expected weight of corresponding size wild fish.

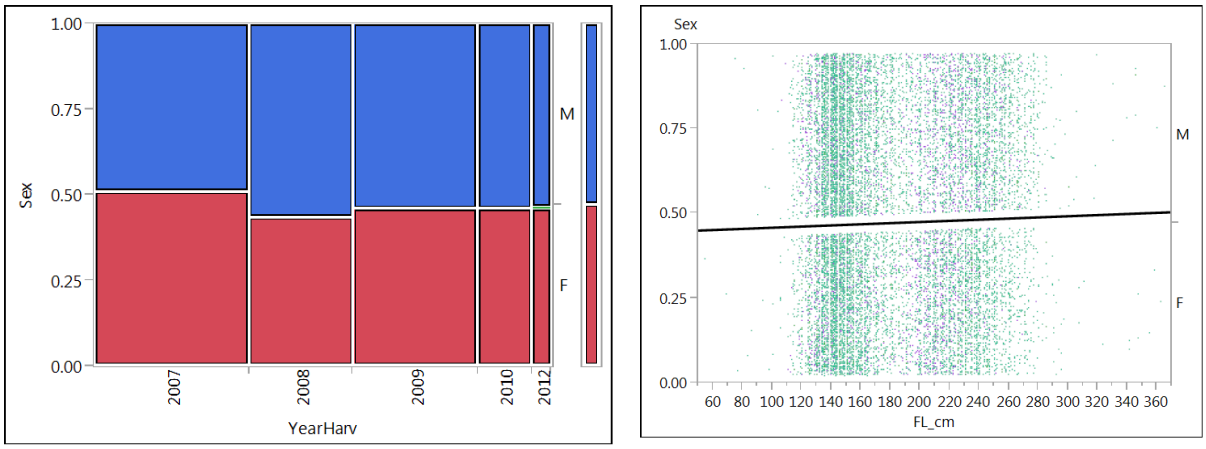


Figure 13. Sex distribution by year (left) and logistic regression of sex ratio at size of harvested bluefin tuna.